BRIEF PRESENTATION OF BIOMECHANICAL RESEARCH CONCERNING HUMAN TOLERANCES UNDER TRAFFIC ACCIDENT CONDITIONS. [1]

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In 1972, the I.R.O. (Institute for Orthopaedic Research) started experiments in the field of impact biomechanics on human subjects in cooperation with the Laboratory of Anatomy of the Unite d'Enseignement et de Recherche "Pitie-Salpetriere" and with the technical assistance of various Manufacturers. (*)

31 tests have been conducted so far:

- 23 simulated frontal collisions with "3 points" belts of various characteristics,
- 3 simulated lateral collisions,
- 3 simulated "vehicle-pedestrian" collisions,
- 2 with a view to analyzing the mechanism of particular pedestrian lesions.

1. - METHODOLOGY -

1.1. The experimental conditions are defined with a view to achieving the best possible realism:

. utilization of production vehicle occupant compartment or prototypes with or without steering device;

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(1) Paper originally presented at International Research Committee on Biokinetics of Impacts, Seminar on "Biomechanics of Human Bodies," held June 11-12, 1974 in Goteborg, Sweden. Reprinted../by Courtesy of Authors and IRCOBI.

(*) those experiments are made only with non-embalmed cadavers, that allows mainly to obtain data about internal organs tolerance and explain some lesions mechanisms.

. location of seat as a function of subject dimensions, etc. . . .

1.2. The preparation of subjects continuously improves:

. restoring of a 15 cm Hg blood pressure in aorta and its branches before, during and immediately after collisions,

. injection of coloured material into blood vessels with a view to revealing vascular vessels ruptures through macroscopic as well as microscopic methods, especially as concerns the central nervous system,

. utilization of devices for estimating brain mass shift and thoracic deflection,

. more recently, control of the volume and pressure of intra-thoracic air.

1.3. The setting out of instruments takes great care of location marks, among others with reference to anatomic marks so as to provide for accurate exploitation by means of computation programs (e.g., calculation of resultant acceleration at the head's center of gravity, both linear and angular, or still torque applied at the occipital condyles).

With a view to allowing the working out of direct relationships between observed lesions and physical parameters, which are used in practice as protection criteria, each test brings into play, under perfectly symetrical conditions, a human subject and a conventional certification dummy.

The number of parameters recorded during each test ranges from 11 to 23 depending on the target.

Systematic complete radiography and autopsy are conducted after each test with sampling of some organs, such as the brain, for further histological analysis.

2.- RESULTS. -

2.1. Lesions are divided into two categories:

(a) 1st category or so-called "energetic" lesions:

- those which obviously are directly related to impact violence; the best example the roof is the more or less severe blow on the thorax.

(b) 2nd category or so-called "circumstancial" lesions:

- those whose eventual occurence depends on contingencies and has no direct relation with impact violence; an example thereof is spleen perforation consequent upon fracture of eighth left rib, fracture which may well be isolated and happen at moderate impact violence.

2.2. For "energetic" lesions in frontal collisions with "3 points" belts, chest fractures are of primary importance and can lead to "flail chest" for very severe impact violence.

The maximum force applied unto superior thoracic anchorage averages 680 daN (*). The maximum resultant force applied to the thorax has been calculated: it is of 765 daN (extreme values 540-990). Finally, the same force, at thoracic rupture, was estimated at 400 daN (extreme values 280-520) (3). (Figure 1).

2.3. It is essential to stress that these thoracic lesions are generally isolated and without associated brain anc cephalic lesions in spite of V's from 50 to 65 km/h and deceleration distance from 37 to 75 cm.

The only severe cephalic lesion for a "3 points" belted occupant was observed on a driver consequent upon a secondary impact against a badly designed prototype steering wheel. It caused a circular fracture at the lower head portion, whose reproduction could be achieved twice whereas the mechanism has been worked out (4).

The scarcity of head and neck lesions in the absence of secondary impact during frontal collisions confirm the results of accidentology (5) (6).

(*) The average corresponding stress is 645 daN for 35 subjects tested by European Teams in DORTMUND (1), HEIDELBERG (2) and PARTS (3).

2.4. The production of these chest lesions may be explained mainly through the deflection of chest as a whole and rib fractures occur in maximum stress areas, which may be located lateral, frontal or at the back.

Rib fractures may be associated with sternum or collarbone fractures.

A proposed classification of chest lesions is based on the number of broken ribs, fracture location, occurence of a multiple rib fracture and, if any, associated sternum and clavicle fractures.

2.5. In 3 out of 23 cases, "energetic" lesions were accompanied by "circumstancial" lesions:

- one case of spleen perforation consequent upon eighth rib fracture,

- one case of subelavian vein perforation consequent upon 1st right rib fracture,

- one case of subelavian artery perforation following collarbone fracture. The above lesion may be considered as fatal.

2.6. In 2 cases out of 23 and because of a bad location of the lower anchorages, we have observed a "sub-marining" which caused fatal lesions (6).

2.7. If, in 20 cases out of 23, thoracic lesions make the overall severity of injuries (O.S.I. from 3 to 5 in the N.A.T.O. scale), we have never observed such severe lesions on real frontal collisions with belted occupants (7) (8). This point must be improved by further research and one must confront two hypothesis:

- tolerances may be different between cadavers and human beings,

- violence level is different in experimental impact and real i impact.

2.8. <u>Utilization of vascular injection for appreciating cephalic lesions</u>.-

Experimental methods based on fresh cadavers so far have provided very few means to locate cerebral lesions. Those are easily observable only for localized impacts causing skull fracture and directly injurying the underlying brain. In the absence of skull fracture, it is necessary to use extremely violent impacts to obtain visible lesions.

Owing to the importance of blood vessel lesions connected with the disease observed after skull traumatisms, we attempted to bring out traumatic blood vessel ruptures on the fresh cadavers used in conjunction with our experiments.

Cerebral vessels are perfused immediately before, during and after the impact, under a Hg pressure of 15 cm, by means of a formol/water mixture containing carbon particles. When no rupture of blood vessels occurs, the mixture is visible solely in small arteries and capillaries (Figure 2). There may also be some in veins. In case of a rupture occuring in meningie vessels, the leak is easily visible, by macroscopy as well as by microscopy. Assuming that the rupture is intra-parenchymateous, the injected mixture percolates into Virchow-Robin sheaths and makes up a pigmented carbon casing around small arteries (Figure 3). When the flow is substantial, the blood vessel leakage may be seen by macroscephic means (Figure 4).

The procedure, on the one hand, makes it easier to locate direct contusions on cerebral hemispheres and by-lesions, and on the other hand, enables us to bring out brain stem bleeding, whose role appears to be of primary importance in traumatic death originating from neurologic causes (Duret-Berner bleeding).

Before taking into account the results obtained by the above procedure, it is necessary to know to which extent it is valid, particularly by seating more precisely vascular brittieness according to the date and causes of death, cooling and preservation in a cool place. Such a study must be conducted on anamils through a comparison of vascular lesions, for similar impacts, as observed on a living animal and a dead animal prepared as mentioned above, the impact being provoked longer or shorter after death.

2.9. Study of brain mass displacement.

We attempted to determine this accurately by securing on the brain pan a rigid metallic rod, 3 mm in diameter and 65 mm in length, which penetrated into the cortex and the white substance of the frontal lobe. A colouring matter made it possible to find out easily the location of the above rod, which is removed immediately after impact on horizontal sections of the secured brain, the relative movement of encephalon and the rod is indicated by a usually linear laceration, whose direction matches with head movement observed by cinematography. The maximum pmplitude of observed movement was 14 mm (Figure 5). It is obviously necessary to specify the influence of the various factors capable of modifying this movement, among others the influence of pressure blood circulation restoring.

3.- GUIDELINES FOR FUTURE RESEARCH.-

Several guidelines were retained:

3.1. Validate the vascular injection lesions for appreciating cerebral lesions through works on animals.

3.2. Find out correlations between volunteers and human cadavers by close cooperation between several research teams.

3.3. Find out correlations between living humans and cadavers by means of real accident simulation.

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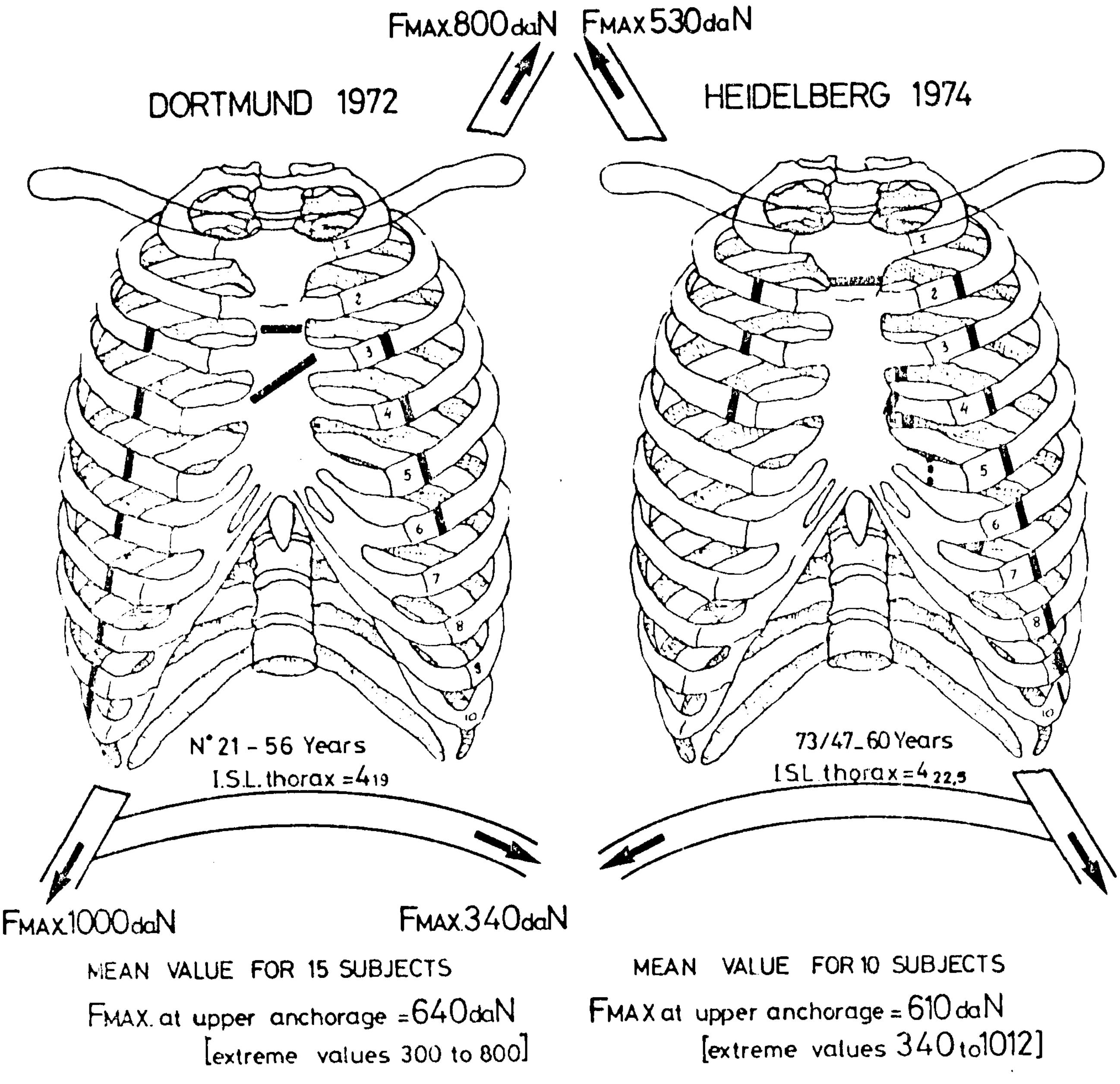

Figure 1 a: Comparison between results of three European Teams

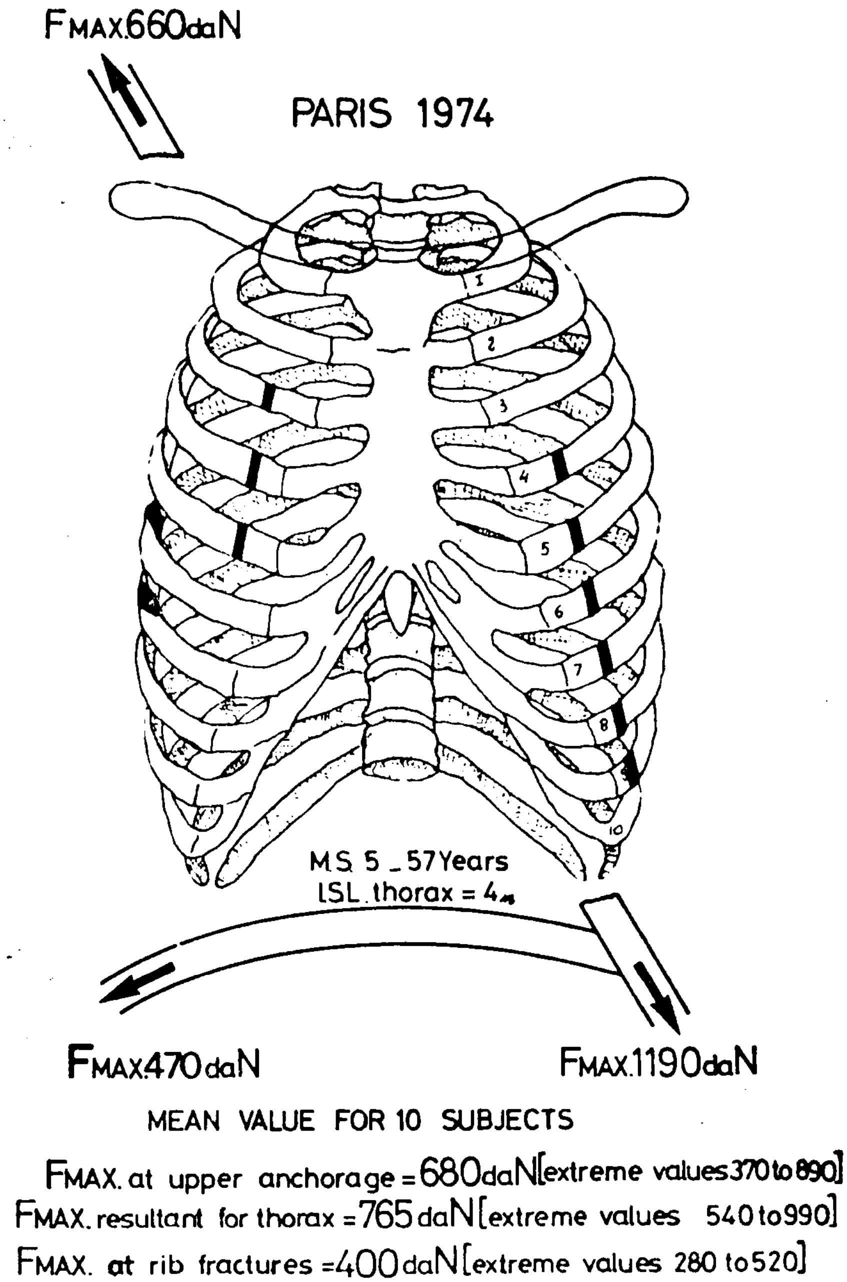

Figure 1 b: Comparison between results of three European Teams

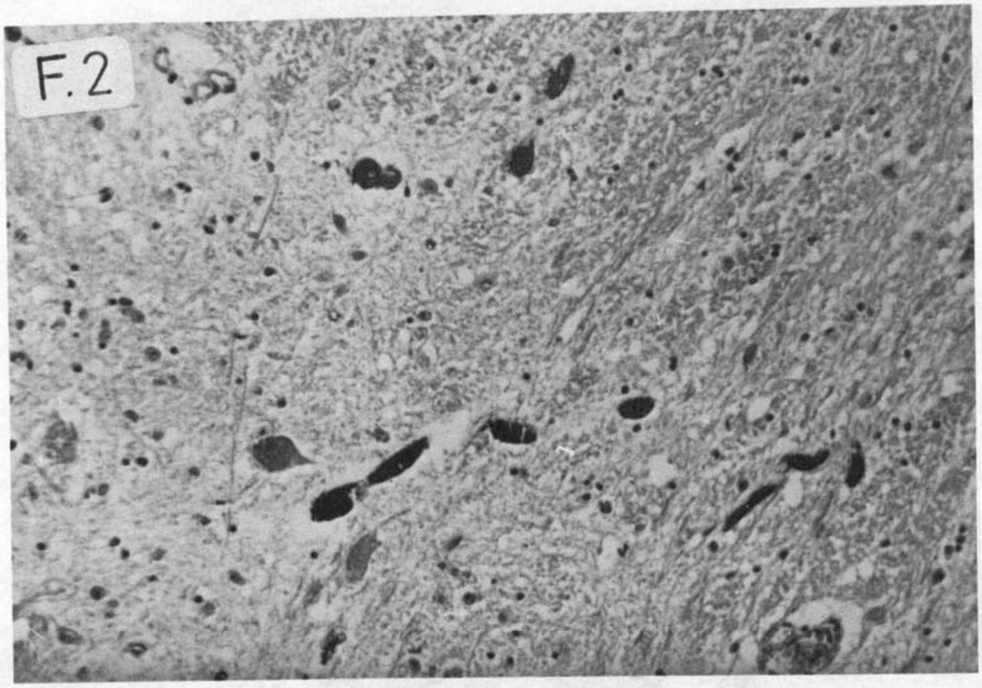

Fig. 2: Capillaries filled with carbon particles. No vascular rupture. Medulla oblongata. Field: 0.72 mm X 0.48 mm.

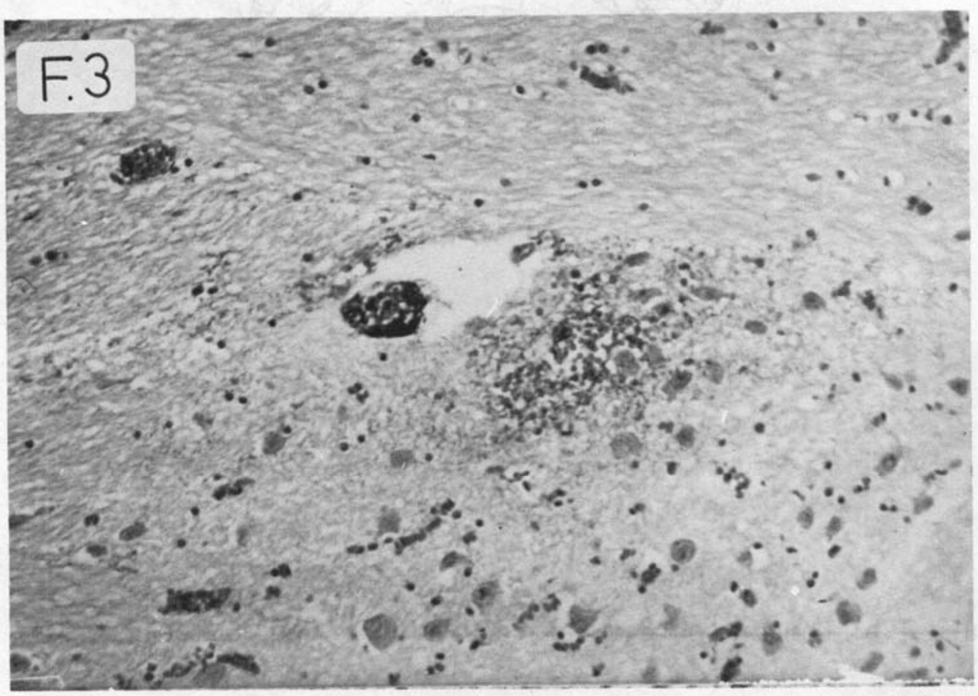

Fig. 3: Carbon particles inside and outside the vessels. Medulla oblongata. Field: 0,72 mm X 0,48 mm.

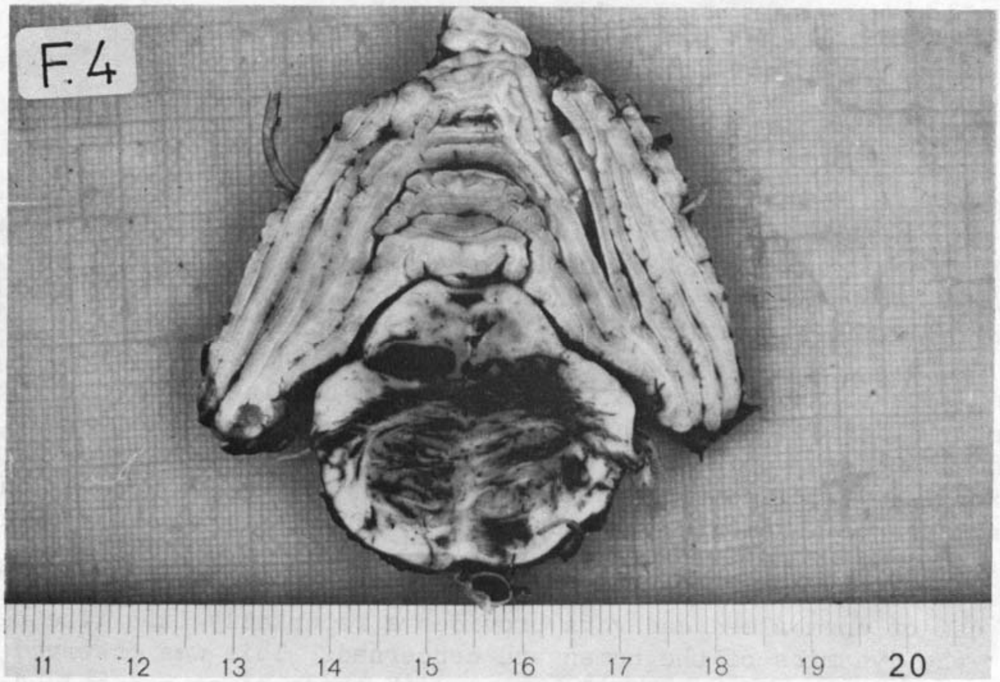

Fig. 4: Accumulation of the india ink outside the vessels in the medulla oblongata. This indicates large tears in the vessels' walls.

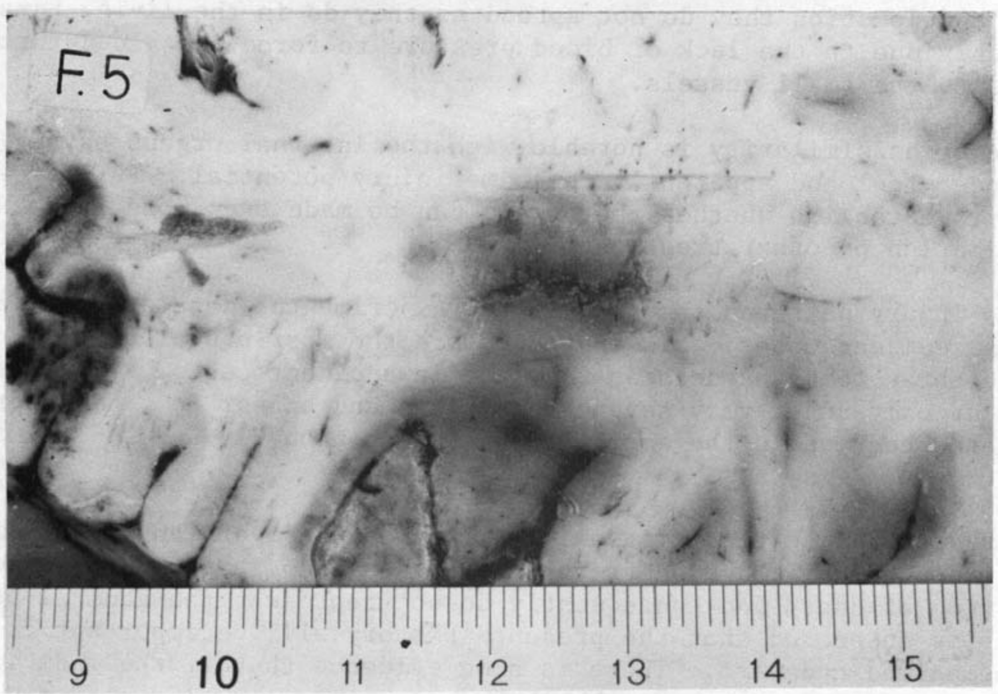

Fig. 5: Laceration of the brain tissue brought by the iron pin in the place of the acceleration (antero-posterior in this case).